REMARKS/ARGUMENTS

The foregoing amendments to claims 28 and 30 remove the references to claim 1, so as to make it clear that they are independent claims. Thus, contrary to what was stated in the official filing receipt, the application contains four independent claims.

In the Office Action of May 20, 2005, the examiner rejected claims 1-3, 8-13, 15 and 23-31 as anticipated by US 5,896,483 (Wojcik *et al.*) and rejected claims 4-7 and 14 as obvious over US 5,896,483 (Wojcik *et al.*). In addition, the examiner rejected claims 16-22 as obvious in view of US 5,896,483 (Wojcik *et al.*) and US 6,016,372 (Fein *et al.*) taken in combination.

These rejections are respectfully traversed on the grounds that the references neither disclose nor suggest a lightguide having means at its output end for imaging non-uniformities present at or adjacent the outlet end of the lightguide away from the predetermined image plane within the apparatus to which the lightguide is connected, and which is being illuminated by the light from the lightguide.

The present invention is primarily concerned with imaging applications, for example microscopy in which the light emitted from the output of the lightguide is used to illuminate an image conjugate plane of the illumination optics within the microscope. In such applications, it is desirable to obtain efficient coupling through the optical train of the microscope, as well as to impose a uniform plane of irradiance. As explained on pages 1 and 2 of the present application, as filed, it has been difficult, in practice, to achieve both uniformity and coupling efficiency. While it is known to improve uniformity by inserting a diffuser between the end of the lightguide and the input port of the apparatus, such a diffuser reduces coupling efficiency. This is particularly so for imaging applications, such as in microscopy, where it is desirable to match the numerical aperture of the objective of the illumination optics.

The present inventors discovered that a primary cause of a lack of uniformity of the light intensity across the image conjugate plane was the presence of virtual images that are produced by the guide, since not only the output end face of the lightguide, but also regions in the vicinity of the output end face, are imaged at certain planes within the microscope. In the case of liquid lightguides, the virtual images arise from light scattering that occurs due to non-uniformities, such as any imperfections at the sheath, the sealing member, or at the interface between the liquid and the sealing member. (The foregoing amendment to page 1 is to clarify that this was not generally known, but rather discovered by the inventors.)

Having recognized this problem, the present inventors addressed it by providing, at the outlet end of the lightguide, imaging means which images the outlet end of the lightguide at the predetermined image plane within the apparatus, e.g., the image conjugate plane in the case of a microscope, but images the non-uniformities away from the predetermined image plane.

While it was implicit from the wording of claims 1, 26 and 30, taken in the context of the disclosure, that the lightguide and "means for displacing" imaged the end of the light guide as well as the non-uniformities, but at different positions, claims 1, 26 and 30 have been amended to make this explicit. In particular, those claims now specify means for "imaging said outlet end of said lightguide at said predetermined image plane within said apparatus and imaging non-uniformities present at or adjacent the outlet end of the lightguide away from said predetermined image plane."

This approach provides uniformity of the light intensity across the predetermined image plane without significantly reduces the coupling efficiency, since it is possible to select the imaging means so that the beam cone angle matches the numerical aperture of the objective of, for example, the microscope.

Neither of the cited references 5,896,483 and 6,016,372 discloses a light delivery system which addresses the lack of uniformity by an imaging technique as taught by the present inventors and which is particularly suitable for imaging applications. In both references, the lightguide and any other elements used in conjunction with it are used for non-imaging applications, sometimes referred to as "light-bucketing".

It is noted that Figures 10 and 11 of the primary reference cited by the examiner, i.e., US 5,684,908 (Kross *et al.*), are identical to Figures 10 and 11 of US 5,896,483 (Wojcik *et al.*) which was cited, and discussed, in the present application. The two patents share three inventors and both were assigned to Southeastern Univ. Research Assn. Inc. Attention is directed to the following discussion of US 5,684,908 in the paragraph beginning at page 2, line 26 of the present application:

> "It is known to obtain a more uniform irradiance distribution by placing a diffuser at the end of a liquid lightguide. United States patent No. 5,684,908 discloses a system for photocuring of chemicals in which such a diffuser changes the shape of the light beam such that the majority of the beam is of a uniform intensity. A drawback to the use of such diffusers, however, is that the resulting optical coupling efficiency to the object to be illuminated, for example, a sample in a microscope, is less than optimal."

Similar considerations apply to cited reference US 5,896,483 in which the light shaping device 26 comprises a lens 54 and a "light shaper" 52. As stated at column 9, lines 36 to 37, "The light exiting the endplug of the light guide retains some of the non-uniformity of the light source. To eliminate this, an inexpensive light shaper 52 is placed in the exiting light path what will eliminate this residual non-uniformity." It is noted that the "non-uniformity" in question here is that of the light source at the input end of the lightguide, not the non-uniformities at the output end of the lightguide. It is apparent from the subsequent discussion in the passage from column 9, line 41 to column 9, line 63 that this light shaper 52 is a diffuser, specifically a holographic diffuser. As is very

well known, such holographic diffusers are most efficient for collimated/normally incident light, and not for the divergent light emitted from the lightguide. This means greater loss of light.

It is important to note that apparent similarities between the light shaping means 26 of US 5,896,483 and the "imaging/displacing means" of the present invention are superficial. Various statements in column 9 of US 5,896,483 make it clear that the lens 52 is simply used to collect light from the lightguide, and not image it. For example, line 13 states that the lens "*maximizes* the delivered effective intensity *at a typical application distance*". Line 33 states that "the lens *gathers* the light and forms a smaller well-collimated spot within a much greater degree of uniformity". (Emphasis added)

These statements clearly indicate that the purpose of the lens is *not* to obtain a high degree or quality of the image of the lightguide, but to simply *collect* or *gather* light from the lightguide. In order to do so, a diffuser 54 is placed as stated in line 55 "either between the outlet endplug of the light guide and the final (biconvex) lens used to collimate the beam (preferred), or just after the lens." By definition, a diffuser "washes out" the relationship of the light rays emanating from an object (in this case, the lightguide), so whether it is placed before or after the final lens, the image of the lightguide is permanently lost within the system.

Since, in line 17, it is stated that the lens "has an F/# which close matches the numerical aperture (NA) of the lightguide," the placement of the light shaping device/diffuser 52 will increase the NA of the light exiting the diffuser, and "overfill" the NA of the lens; therefore light will be lost. Consequently, the higher degree of diffusion will allow for better uniformity, but at the cost of a loss of energy from the system. This is a typical trade-off in the field of non-imaging optics. Since sources of light are non-uniform by nature, diffusing elements can be used to "smear out" the distribution of light, while losing some light. In non-imaging terms, the diffuser 52 is not an etendue maintaining optical element since it will always increase the etendue (E) of the light. In other words, the product of $A^*\Omega = E$ of the light beam will be larger after propagation through the diffuser and, therefore, a fundamental physical upper limit is placed upon the ability to capture the light into a small area or angular extent. (In this case it will be physically impossible for all the light to be captured by the lens after inclusion of the diffuser 52). Here A is the area of the beam at a particular plane, and W is the solid angle of the light at that same plane. If a "magical" LSD diffuser could provide for, say, a 5 degree increase in cone angle, this would imply a significant loss of light. By way of example, if the light exiting the lightguide is of NA=0.22, the beam angle is approximately 12.7 degrees. A 5 degree LSD would increase this beam angle to 17.7 degrees, resulting in a doubling of the solid angle (which is proportional to the square of the sine of this angle), which results in a loss of 50% when coupling to an imaging system with NA=0.22.

US 5,896,483 makes no mention of the use of imaging optics at the output end of the lightguide to correct for lack of uniformity by imaging non-uniformities away from the predetermined image plane. It follows that claims 1, 26 and 30 are not anticipated by US 5,896,483. Each of claims 2, 3, 8-13, 15, 23-25 and 27-31 is dependent upon one of claims 1, 26 and 30 and so includes all of its feature; hence, claims 2, 3, 8-13, 15, 23-25 and 27-31 are not anticipated by US 5,896,483. Notwithstanding that, it is noted that these dependent claims themselves introduce other combinations of features which, though not discussed here, are considered to be novel in their own right.

Regarding the rejection of claims 4-7 and 14 as obvious, US 5,896,483 not only does not disclose the use of an imaging device to image non-uniformities at or adjacent the end of the lightguide away from the predetermined image plane, but also does not suggest it. Indeed, it does not even identify the problem and its use of a diffuser precludes the use of an imaging device according to the present invention. Consequently, not only would the skilled addressee not be led or motivated to make the modifications or substitutions suggested by the examiner, but, even if he did, it would not result in the present invention. It follows that claims 4-7 and 14 are not rendered obvious by US 5,896,483.

Claims 16-22 were rejected over a combination of US 5,896,483 and US 6,016,372. As discussed above, US 5,896,483 neither discloses nor suggests using an imaging device according to the present invention. Indeed, it fails to identify the problem identified by the present inventors and its use of a diffuser precludes the use of an imaging device according to the present invention. Consequently, a skilled person would not be led or motivated to make the combination suggested by the examiner. Indeed, even if the skilled addressee did so, the result would not be in accordance with claim 1, 26 or 30 because it would not result in a light delivery system having means for imaging the non-uniformities away from the predetermined image plane.

In conclusion, the present invention is predicated upon the recognition and explanation of virtual source images of non-uniformities produced when imaging the output of a liquid lightguide as a cause of a lack of uniformity of irradiance across the predetermined image plane. To the best of the present inventors' knowledge and belief, they were the first to do so. Having identified the nature of the problem, the inventors went on to address it by imaging the non-uniformities away from the predetermined image plane. Since neither of the cited references mentions the stated problem of virtual source planes, etc., as discussed on pages 8 and 9 of the present application, it is not surprising that they neither disclose nor suggest addressing the problem in the manner of taught by the present inventors.

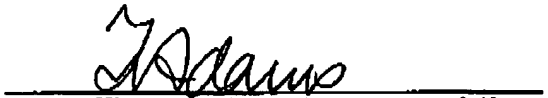
This opportunity has been taken to correct some minor deficiencies in the claims, such corrections being self-evident, and to add new claims 32 to 36 which are dependent directly or

indirectly upon claim 1 and are directed to a microscope and light delivery system. In addition, new claims 37 and 38 dependent directly or indirectly upon claim 29, and claim 39 dependent upon claim 15, have been added to specify that the imaging means could be a lens means and/or integral with the outlet end of the lightguide or rod. New claim 40 is similar to claim 22 but covers the non-collimated case. Support for claim 40 is provided by Figures 4 and 5. No new subject matter has been added by claims 32 to 40. It is submitted that claims 32 to 40 are patentable over the cited references for the reasons set forth in relation to claims 1, 26 and 30 and their dependent claims.

References to "conjugate plane" on pages 2 and 11 have been amended to read "image conjugate plane" for consistency with the use of the latter term in claim 32.

In view of the foregoing, it is submitted that all claims of record are patentable over the cited references and early and favourable reconsideration of the application is respectfully requested.

Respectfully submitted,



Thomas Adams, Reg. No. 31,078